UNIVERSITI PUTRA MALAYSIA

CRASHWORTHINESS INVESTIGATION OF CERVICAL SPINE INJURIES AMONG MOTORCYCLISTS IN MALAYSIA

OOI SOO SHEN

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By

OOI SOO SHEN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirements for the Degree of Master of Science

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This work is dedicated to

all my teachers and friends that show me the fund of education.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

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Chairman: **Wong Shaw Voon, Ph.D.**

Faculty: **Engineering**

This study looks at cervical spine injuries sustained by motorcyclists in motorcycle road crashes. There are hardly any studies on cervical spine injury of motorcyclists compared to studies on injuries sustained by car passenger during crash. The motorcycle rider is relatively more exposed to road hazards compared to a protected car passenger. They are therefore more prone to injury than those traveling in any other form of transport. The motorcycle is relatively less stable and accorded little protection to riders in road crashes compared to a four-wheeled vehicle. The cause of injury and injury mechanisms are more uncertain for a motorcyclist compared to a car driver. The objective of the present study is to correlate the motorcycle crash mode to the cervical injury sustained by motorcyclists in real-world scenes. The findings of the study unveiled ideas and information to safety engineers on designing a motorcycle restrain system as injury mechanisms were pre-determined. Motorcyclists with cervical injuries admitted to the hospitals were selected for the present investigation. The types of injury sustained were acquired from the medical report. Information on the crash scene and crash mode was obtained from the police report and interview session arranged with the motorcyclist involved in the crash.

Statistical analysis shows that the vehicle crash mode is significant in determining the cervical injury mechanism ($p < 0.05$), and thus some pre-determined basic injury types have been observed. The neck flexion and extension movements were the most frequent neck injury mechanisms, especially in frontal and rear end impacted motorcycles. Burst fractures were commonly observed in frontal impacts, while side impact and skidded motorcyclists were found to have a high frequency of uncinate process fractures, a result of neck lateral flexion. The head injuries did not contribute to the severity of cervical injury ($p > 0.05$). Further analysis resolved a hypothesis that helmet might increase the severity of cervical spine at rear end impacted motorcyclists. With the assumption made that neck muscles mostly were activated and protected the cervical structure at frontal crash but not in other mode of crashes, statistical analysis showed that motorcyclists with helmet and crash at rear-end or side modes were prone to sustain severe cervical injury (Non-parametric Spearman correlations: 0.327, significant at 0.05 level). On the other hand, helmeted motorcyclists at frontal crash were more protected from the severe injury consequences (Non-parametric Spearman correlation: -0.554, significant at 0.01 level). The reduction of energy in direct crash impact by helmet to the head had reduced the severity of injured cervical spine. But the protector (helmet) itself has became a hazard that makes the cervical structure sustain more load, especially in rear-end collision when the head flexes or rebounds without the support from neck muscles. This information should be served as a basis for any further action to be taken in injury prevention for motorcycle road crash. These cervical spine injury severity models in motorcycle road crash have been developed using logistic method at the end of study. Based on the fundamental knowledge in human anatomy and mechanics, the angle of neck movement

can be calculated. Further analysis on tissue element and bone stiffness may provide further information in designing a proper cervical restrain system. Such system should alleviate the severity of the incidence of cervical spine injury and the attendant consequences resulting from the motorcycle road crashes.

Abstrak thesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PENYIASATAN *CRASHWORTHINESS* BAGI KECEDERAAN LEHER PADA PENUNGGANG MOTOSIKAL DI MALAYSIA

Oleh

OOI SOO SHEN

September 2003

Pengerusi: **Wong Shaw Voon, Ph.D.**

Fakulti: **Kejuruteraan**

Kecederaan leher pada para penunggang motosikal merupakan satu masalah di negara ini. Keparahaan saraf tunjang *cervical* yang berpunca daripada kemalangan jalan raya bukan sahaja membebankan pengurusan hospital tetapi keluarga mangsa, malah ia merupakan satu kepahitan hidup yang perlu diharungi si mangsa dalam hidupnya. Dengan angka statistik yang menunjukan kecederaan leher merupakan punca ketiga besar bagi kematian penunggang motosikal di jalan raya. langkah yang proaktif perlu diambil segera untuk menangani masalah ini. Kajian ini mengambil langkah untuk memahami mekanisma kecederaan tulang belakang *cervical* pada para penunggang motosikal di negara ini. Diagnosis perubatan bagi kes-kes yang melibatkan kecederaan leher diperoleh daripada hospital. Maklumat dan keterangan mengenai kejadian kemalangan kemudian dicatat melalui laporan polis dan sesi temuramah dengan mangsa kemalangan. Data yang dikumpul kemudian disusun dan dianalisis dengan menggunakan kaedah statistik.

Keputusan daripada analisis menunjukkan mekanisma kecederaan *cervical* berkait rapat dengan jenis perlanggaran motosikal ($p< 0.05$). Maklumat ini adalah penting agar jurutera dapat membentuk satu strategi and plan tindakan yang efektif bagi mengurangkan keparahan kecederaan semasa kemalangan jalan raya. Keputusan analisis juga menafikan hipotesis bahawa kecederaan pada bahagian kepala akan meningkatkan keparahan *cervical*. Walau bagaimanapun, jika perlanggaran berlaku pada bahagian belakang ataupun sisi motosikal, penggunaan topi keledar didapati mempunyai kesan dalam meningkatkan keparahan *cervical*. Ini berlaku apabila otot leher yang berfungsi dalam pengstabilan struktur *cervical* tidak berfungsi. Penunggang motosikal biasanya tidak sedar akan kejadian yang akan menimpanya dan pengaktifan otot leher jarang berlaku apabila mereka dilanggar dari belakang (pengaktifan otot memerlukan masa 60ms, manakala kecederaan pada *cervical* dicatatkan berlaku dalam masa 15ms selepas dikenakan hentakan). Kebarangkalian keparahan bagi penunggang motosikal yang berlanggar depan dan bertopi keledar adalah rendah berbanding dengan yang tidak bertopi keledar (OR: 0.53; 95% CI: 0.05-0.596). Keadaan ini mungkin disebabkan oleh kebolehan topi keledar yang telah menyerap sebahagian tenaga hentakan dan wujudnya otot leher yang berfungsi dalam pengstabilan struktur leher.

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I certify that an Examination Committee met on 11th September 2003 to conduct the Final examination of Ooi Soo Shen on his Master of Science thesis entitled "Crashworthiness Investigation of Cervical Spine Injuries among Motorcyclists in Malaysia" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee Recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Abdel Magid Hamouda, Ph.D.
Faculty of Engineering
University Putra Malaysia
(Chairman)

Wong Shaw Voon, Ph.D.
Faculty of Engineering
University Putra Malaysia
(Member)

Radin Umar Radin Sohadi, Ph.D.
Professor
Faculty of Engineering
University Putra Malaysia
(Member)

Megat Mohamad Hamdan Megat Ahmad, PhD.
Associate Professor
Faculty of Engineering
University Putra Malaysia
(Member)

GULAM RUSUL RAHMAT ALI, Ph.D.
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 28 JAN 2004

This thesis submitted to the Senate of University Putra Malaysia has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

Wong Shaw Voon, Ph.D.
Faculty of Engineering
University Putra Malaysia
(Chairman)

Radin Umar Radin Sohadi, Ph.D.
Professor
Faculty of Engineering
University Putra Malaysia
(Member)

Megat Mohamad Hamdan Megat Ahmad, Ph.D.
Associate Professor
Faculty of Engineering
University Putra Malaysia
(Member)

Azhar Abdul Aziz, Ph.D.
Associate Professor
Hospital University of National
(Member)

AINI IDERIS, Ph.D.
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 0 3 FEB 2004

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

OOI SOO SHEN

Date: 26 JAN 2004

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AIS	Abbreviated Injury Scale
CT	Computer Temography
HKL	Hospital of Kuala Lumpur
HUKM	Hospital of University Kebangsaan Malaysia
ISS	Injury Severity Score
MRI	Magnetic Resonance Image
PDRM	Royal Malaysia Police
RSRC	Road Safety Research Center
SCI	Spinal Cord Injury
SPSS	Statistical Package for Social Science
UPM	University Putra Malaysia

CHAPTER 1

INTRODUCTION

"All injury leaves pain in the memory except the greatest injury, that is death, which kills memory with life." This is how *Leonardo da Vinci*, (1452-1519) code about injury, with injury comes the inevitable physical, emotional, and economic costs, as well as loss of time and normal function. No one can spare for the pain, distraction, and incapacity caused by injury. Today, injury is considered as one of the serious public health problems and became challenges faced by today scientists. In developed countries like United State of America. the National Safety Council (U.S.) estimated that 1996 annual cost of injury was near $435 billion and that about 40% were admissions to hospital emergency rooms or hospital clinics for treatment of injury, part of this figure is due to road traffic crash.

As global society became more and more advanced, trauma injuries arise from traffic has become one of the most common threats of health arising fast. One of the issues still, concerning many scientists in this millennium is road crash trauma. As the developing country's economy improves, it is expecting the vehicle use in world population will increase extensively. By year 2020, it is expecting traffic related fatalities in developing world will rise to 1 850 000 per year, and road traffic crash will become one of the three main causes of disability (Mackey, 2000). Scientific investigation has further concluded head-neck and chest injury contributed much to mortality and morbidity in road crash (Chiang et al. 1997).

Back to environment in Malaysia, the increasing of social economic activities has, at the same time, increase the vehicles moveable volume in the country. Statistics from Road Transport department, Malaysia shows half of the registered vehicles used on road are motorcycles. This development has contributes to the increasing of vehicle collisions in the country, especially in urban area. Other words, the casualties have increased folds back to several decades ago. The injury caused by road crash has been placed third causes of hospitalization in government hospitals in year of 1995, immediately after normal delivery and complications of pregnancy (Health Facts, 1997). As it, road crash injury should be seen as one of the threat to living quality for Malaysian.

The alarming fatality arisen as well has pushed the authority to call for serious attention from various organizations. Researchers and engineers were called to resolve the situation. Preliminary investigation revealed that head, chest and neck injuries were risks faced by motorcyclists in road crashes. Although statistically, most casualties sustained limb injuries, authorities are more concerned about injuries to the vital parts like head and neck as it can lead to complications. The severely injured neck resulted from road collision may cause permanent disability due to paralysis, stiffness, pain, numbness, giddiness or other complaints, if not threaten life.

To alleviate this problem, a good strategy and plan are needed. It is important to understand how motorcyclists sustain the injuries and the causes of injury prior to developing proper restrain devices or strategies to prevent its occurrence. Unfortunately, few studies have been carried out in this area, especially in relation to the motorcycle.

This could be attributed to differences in use of the motorcycle between countries. The motorcycle is a leisure sports vehicle in most developed countries like the United States of America, but in developing countries such as Malaysia and Taiwan the vehicle is used as a mode of transport. Although some motorcycle companies have carried out some laboratory crash tests, efforts have been largely direct at the head and lower limbs. Much attention has not been paid to neck injuries.

In most advanced automotive research laboratories, investigations have been directed at establishing other injured body parts than head in vehicle crash. "Whiplash injury" for example. a soft tissue injury cause by rear-end car collision, has call for serious attention. The whiplash-associated disorders although categorized as minor injury, but it is been recorded as the most common disability injury in Sweden (Svensson, 2000). In developing country, most of the neck related injuries came from motorcycle road crashes. For instance, the motorcycle road crash has been known as major cause of spinal cord injury (SCI) in Taiwan and the incidents of SCI in Hualien have been recorded as the highest in the world (Hou, 1998). A study done in Thailand reviewed about 80% of the traumatic brachial plexus injuries were caused by motorcycle accidents (Songcharoen, 1995).

Study conducted in Road Safety Research Center (RSRC), University Putra Malaysia (UPM) had shown evidence that cervical injury sustained by motorcyclists in road collision caused mortality. The cervical injury consist about 60% of all vertebral injuries that causing death to motorcyclists, involved in road collision and admitted to hospitals

(Pang, 2000). The injury has been categorized as one of the most single cause of fatality to motorcyclists.

An in-depth investigation on the subjects is thus needed. The study of injury mechanisms and its close associated factors are necessary. To do so, relationship between injury outcome and their kinematics prior to the vehicle crash is important. With suggestions given by previous study, the injury was reported to be associated with the impact to the head and consequently energy loading to the neck, as a result of the inertia mass of the torso. The relationship between the head and the cervical injury in motorcycle road crash is needed to give a closer conclusive result.

On the other hand, the lack of real-world data in supporting laboratory findings is part of the reason why the cervical injury mechanisms in frontal and rear-end impact are still not known. This is where present study is needed with the design of data collection from real-world scenario.

1.1 Rationales of the Study

The reductions in motorcyclist fatality, as well as injury frequency are important to avoid economic lost bared by country. Beside safer road engineering and better technology design, any action or intention in helping the motorcyclists should bring a better understanding in terms of causes and injury mechanisms. Hence, present study was carried to give clear relationships about the cause of neck injury and the factors that closely associated with the severity of such injury.

In brief, the rationales behind the present study are:

1. Motorcyclists are faced with high fatality and injury risk involving road crash.
2. Neck injury is one of the major factors contributed to motorcycle fatality in road crash.
3. Cervical spine injuries usually carry severity and have caused permanent impairment and long recovery period, if not fatality.
4. Very few studies have been carried out on cervical spine injuries of motorcyclist involving road crash.
5. It is important to understand how motorcyclists sustain the injuries and the causes of injury prior to developing proper restrain devices or strategies to prevent its occurrence.